

# Axessibility: creating PDF documents with accessible formulae

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## Sommario

I documenti PDF contenenti formule generati da  $\text{\LaTeX}$  non sono solitamente accessibili mediante tecnologie assistive per persone con disabilità visive (i.e., screen reader e barre Braille). Il pacchetto  $\text{\LaTeX}$  `axessibility.sty` da noi sviluppato risolve questo problema, permettendo di creare documenti PDF in cui le formule vengono lette da tali tecnologie assistive. Infatti, vengono generati automaticamente dei commenti nascosti nel documento PDF (mediante l'attributo `/ActualText`) in corrispondenza di ogni formula. Tale testo alternativo risulta nascosto nel documento PDF, ma gli screen reader Jaws, NVDA e VoiceOver vi accedono correttamente. Inoltre, abbiamo creato dei dizionari (in inglese e italiano) per NVDA e Jaws che forniscono la lettura delle formule in linguaggio naturale nel caso in cui l'utente non conosca i comandi  $\text{\LaTeX}$ . Il pacchetto non genera PDF/UA.

## Abstract

PDF documents containing formulae generated by  $\text{\LaTeX}$  are usually not accessible by assistive technologies for visually impaired people (i.e., by screen readers and braille displays). The  $\text{\LaTeX}$  package `axessibility.sty` that we developed manages this issue, allowing to create PDF documents where the formulae are read by these assistive technologies, since it automatically generates hidden comments in the PDF document (using the `/ActualText` attribute) in correspondence to each formula. This actual text is hidden in the PDF document, but the screen readers Jaws, NVDA and VoiceOver read it correctly. Moreover, we have created NVDA and Jaws dictionaries (in English and in Italian) that provide the reading in the natural language in the case that the user does not know the  $\text{\LaTeX}$  commands. The package does not generate PDF/UA.

## 1 Introduction

In this paper, we describe `axessibility.sty`, a  $\text{\LaTeX}$  package which allows to automatically generate a PDF document with formulae accessible by assistive technologies for visually impaired people. Assistive technologies (screen readers and braille displays) perform satisfactorily with regard to digital documents containing text, but they still have

a long way to go as far as formulae and graphs are concerned. A comprehensive overview about this problem can be found in ARCHAMBAULT *et al.* (2007) and ARMANO *et al.* (2014).

Many studies have been conducted in order to improve the accessibility of digital documents with mathematical contents. For instance, MathPlayer ensures accessibility of formulae inserted by using MathType in Word documents SOIFFER (2018). Another way for creating accessible mathematical documents is given by the MathML language (see BERNAREGGI e ARCHAMBAULT (2007) for further information). However, accessibility of such documents is heavily affected by the versions of browsers, operating systems and screen readers, making this solution very unstable. A system used by blind people for reading and writing mathematics is the LAMBDA system (Linear Access to Mathematics for braille Device and Audio-synthesis). Mathematical language in LAMBDA is designed so that every symbol can be directly translated into words. For further details on LAMBDA we refer to BERNAREGGI (2010). Unfortunately, this system does not help to spread accessible digital documents, since it is only used by visually impaired people and it is not a standard for the realization of documents by sighted people. Regarding  $\text{\LaTeX}$ , assistive technologies can directly manage  $\text{\LaTeX}$  documents. In this case, visually impaired people need to learn  $\text{\LaTeX}$  in order to understand the commands. However, there are software which facilitate  $\text{\LaTeX}$  comprehension and usability; one of them is BlindMath PEPINO *et al.* (2006). Moreover, some converters from  $\text{\LaTeX}$  to braille exist, see, e.g., PAPASALOUIROS e TSOLOMITIS (2017) and BATUSIC *et al.* (1998).

In general, the most widespread digital documents are in PDF format. However, in the case of mathematical contents, they are not accessible at all, since formulae are usually unreadable by screen readers because they are bidimensional as images. None of the above systems allows to directly produce accessible formulae in PDF documents. This could be possible only performing specific tasks. For instance, using the Word editor, if each formula is manually tagged by the author (by using the alternative text), such a comment will be kept when the corresponding PDF file will be generated and it will be read by the screen reader. However, this

procedure does not help to improve the presence of accessible PDF documents, since it is a very boring and time consuming method. It is very hard to think that an author performs these actions for the realization, e.g., of a book. Currently, a standard and fast method for inserting accessible formulae into a PDF documents is still lacking despite it is a very important issue for spreading accessible digital scientific documents. In UEBELBACHER *et al.* (2014) standard guidelines for accessibility of PDF documents are presented. Moreover, in MOORE (2009), MOORE (2014) and BORSERO *et al.* (2016), an overview about accessibility of PDF documents is provided with a focus on mathematical contents.

In this paper, we show the features of the package `axessibility.sty` (whose a first version is also described in ARMANO *et al.* (2018)) that provides the first method for an automatized production of accessible PDF documents with mathematical contents. We would like to highlight that this package does not produces fully tagged PDF, such as the standard PDF/UA, but it allows to obtain a PDF where formulae are described using the `/ActualText` attribute.

## 2 Problem Statement

When a PDF document is generated starting from  $\text{\LaTeX}$ , formulae are not accessible by screen readers and braille displays. They can be made accessible by inserting a hidden comment, i.e., an actual text, similarly to the case of web pages or Word documents. This can be made, e.g., by using the  $\text{\LaTeX}$  package `pdfcomment.sty` or using an editor for PDF files like Adobe Acrobat Pro. In any case, this task must be manually performed by the author and it is surely inefficient, since the author should write the formulae and, in addition, insert a description for each formula. Note also that the package `pdfcomment.sty` does not allow to insert special characters like *backslash*, *brace*, etc, in the comment. Moreover, with these solutions, the reading is bothered, since the screen reader reads incorrectly the formula and then the correct comment of the formula.

In Figure 1, we show the PDF document generated from the following  $\text{\LaTeX}$  code containing a simple formula with a comment manually inserted.

```
\documentclass{article}
\documentclass[a4paper]{article}
\usepackage{pdfcomment}
\begin{document}
A simple formula:
\begin{equation}
\pdftooltip{
  \frac{1 + \sqrt{5}}{2}
}{
  begin fraction numerator 1 +
  square root of 5 over 2
  end fraction
}

```

```
\end{equation}
\end{document}
```

When the screen reader accesses the PDF document, the formula will be read

square root 1 plus 5 2 begin fraction numerator 1 plus square root of 5 over 2 end fraction

i.e., before reading the correct comment

begin fraction numerator 1 plus square root of 5 over 2 end fraction

the screen reader reads incorrectly the formula

square root 1 plus 5 2.

A simple formula:

$$\frac{1 + \sqrt{5}}{2} \quad (1)$$

begin fraction numerator 1 +square root of 5 over 2 end fraction

FIGURA 1: PDF document generated using the package `pdfcomment.sty`

There are also some  $\text{\LaTeX}$  packages that try to improve the accessibility of PDF documents produced by  $\text{\LaTeX}$ . In particular the packages `accsupp.sty`<sup>1</sup> and `accessibility_meta.sty`<sup>2</sup> has been developed in order to obtain tagged PDF documents. However, both packages do not solve the problem of the accessibility of formulae.

## 3 axessibility.sty $\text{\LaTeX}$ package

Our package, named `axessibility.sty`, solves the problem described in the previous section. It achieves that by inserting a hidden comment in the PDF file corresponding to any given formula. This comment, named `/ActualText`, contains the original  $\text{\LaTeX}$  commands used to generate the formula. The hidden comment is read by screen readers and braille displays instead of the ASCII representation of the formula, which is often incorrect.

### 3.1 Usage

Authors that would like to create an accessible PDF document for visually impaired people only need to include the `axessibility.sty` package into the preamble of their  $\text{\LaTeX}$  project. Mathematical environments will then automatically produce the `/ActualText` content and include it in the produced PDF file.

We have treated the most used environments for inserting formulae, i.e., `equation`, `equation*`, `\[`,

1. available at <https://ctan.org/pkg/accsupp>

2. available at <https://github.com/AndyClifton/AccessibleMetaClass>

\(. Hence, any formula inserted using one of these environments is accessible in the corresponding PDF document. Additionally, the package enables to copy the formula  $\LaTeX$  code from the PDF reader and paste it elsewhere.

Note that, to preserve the compatibility with Acrobat Reader, our package discourages the use of the underscore character `_` which is not correctly read using screen readers in combination with this PDF reader. Alternatively, we suggest to use the equivalent command `\sb`.

In-lined and display mathematical modes ( $\$, \$\$$ ) are not supported in this version of the package. However external scripts provided as companion software can also address these use cases.

If we use the package `axessibility.sty` applied to the previous example, we obtain the following  $\LaTeX$  code.

```
\documentclass[a4paper,11pt]{article}
\usepackage{axessibility}
\begin{document}
  A simple formula:
  \begin{equation}
    \frac{1 + \sqrt{5}}{2}
  \end{equation}
\end{document}
```

We observe that, in this case, the author has to write the formula without adding anything else. Moreover, inside the source code of the PDF file, we find an `/ActualText` tag with the  $\LaTeX$  code inside, automatically generated by the `axessibility.sty` package.

```
/S/Span<</ActualText(\040\040\
  \frac\040{1\040+\040\sqrt
\040{5}}{2}\040)>>BDC
```

The screen reader will read correctly the  $\LaTeX$  command `\frac {1+ \sqrt {5}}{2}`. Moreover, we have created JAWS and NVDA dictionaries that provide the reading in the natural language in the case that the user does not know the  $\LaTeX$  commands.

### 3.2 Technical Overview

`axessibility.sty` first defines a pair of internal commands (`\BeginAxessible` and `\EndAxessible`) which redefine `\BeginAccSupp` and `\EndAccSupp` as follows:

```
\newcommand*{\BeginAxessible}[1]{%
  \begin{group}
    \setkeys{ACCSUPP}{#1}%
    \edef\ACCSUPP@span{%
      /S/Formula<<%
        \ifx\ACCSUPP@Alt\relax
        \else
          /Alt\ACCSUPP@Alt
        \fi
        \ifx\ACCSUPP@ActualText\relax
        \else
          /ActualText\
            \ACCSUPP@ActualText
```

```
        \fi
      >>%
    }%
    \ACCSUPP@bdc
    \ACCSUPP@space
  \end{group}
}
```

Precisely, `\BeginAxessible` adds a hidden comment that starts with `/S/Formula` instead of `/Span`.

```
\newcommand*{\EndAxessible}{%
  \begin{group}
    \ACCSUPP@emc
  \end{group}
}
```

The second building block of this package is the wrapper. This routine takes the  $\LaTeX$  code inside the formula, removes the tokens and passes it to `\BeginAxessible`.

```
\long\def\wrap#1{
  \BeginAxessible[method=escape,
    ActualText=\detokenize\expandafter
    {#1}, Alt=\detokenize\expandafter
    {#1} }
  #1
  \EndAxessible%
}
```

Finally, using the wrapper, we can re-define the mathematical environments using the command above. Here is an example using `equation`.

```
\renewenvironment{equation}{%
  \incr@eqnum
  \mathdisplay@push
  \st@rrredfalse \global\@eqnswtrue
  \mathdisplay{equation}%
  \collect@body\wrap\auxiliaryspace}{%
  \endmathdisplay{equation}%
  \mathdisplay@pop
  \ignorespacesafterend
}
```

## 4 Conclusions and Future Work

We have developed a  $\LaTeX$  package that automatically generates comments to formulae when the PDF document is produced by  $\LaTeX$ . The comments are hidden in the PDF document and they contain the  $\LaTeX$  commands that generate the formulae. In this way, an accessible PDF document containing formulae is generated. Indeed, screen readers are able to access the comment when processing a formula and reading it. Moreover, we have created JAWS and NVDA dictionaries that provides the reading in the natural language in the case that the user does not know the  $\LaTeX$  commands.

There are a few issues that are yet to be solved with a pure  $\LaTeX$  solution. Namely,

- In-line and displayed mathematical environments delimited with `$`, `$$`,
- User-defined Macros,
- Multi-line environments such as `\align` and `\eqnarray`.
- Semantic description of formulae.
- PDF/UA.

We have resolved the first two problems using an external script – `axesscleaner.py` – coded in Perl and Python. The script also beautifies the L<sup>A</sup>T<sub>E</sub>X file and removes all the *underscore* characters `_`, replacing those with `\sb`. Using this solution we are now able to apply `axessibility.sty` to entire textbooks that were written without using the package in the first place.

Multi-line environments are going to be treated using a L<sup>A</sup>T<sub>E</sub>X solution that is currently in the test phase. Concerning the last two problems a more in-depth research is in order. The authors are currently initiating the investigation to address these issues as a future work.

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